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## Anatomy of the Elephant's Ear,

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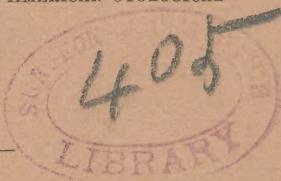


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[Reprinted from the TRANSACTIONS OF THE AMERICAN OTOLOGICAL  
SOCIETY, 1890.]



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## A REVISED DESCRIPTION OF THE ANATOMY OF THE ELEPHANT'S EAR.

By ALBERT H. BUCK, M. D., *New York, N. Y.*

The discovery made by Dr. Richards, that the plane of section, which I had taken to be a horizontal plane, was in reality vertical, renders a large part of the description which I published in the Transactions of 1888 inaccurate. The restrictions under which I was placed by Prof. Wilder, who desired to preserve the specimen in as perfect a condition as possible for the Cornell Museum of Anatomy, rendered it an easy matter to be misled in regard to the true relations of these different sawed surfaces, to a vertical antero-posterior and a vertical transverse plane, and this must serve as my apology for the error which I was so unfortunate as to make. Thanks to the removal of these restrictions at a later date by Prof. Wilder, my colleague has been enabled to study the specimen more thoroughly than I could, and he has determined accurately the relations of these different parts. With the Society's permission, therefore, I submit herewith, for publication in this year's volume of the Transactions, a corrected version of the account which was printed year before last.

The specimen had been sawed out from the skull in such a manner as to show four plane and two uneven surfaces. The plane surfaces are: a vertical one, which is situated just in front of the external auditory canal and middle ear, leaving both of them intact, but traversing many

of the large air cells which surround these parts; an inferior transverse section, which bisects the lower end of the middle ear a short distance below the point where it merges into the Eustachian tube; a superior horizontal section which passes through an intercommunicating system of air cells; and, finally, a median vertical section which leaves one condyle of the occipital part of the occipito-vertebral articulation attached to the specimen. The outer and posterior face of the specimen represents the natural surface of the skull as it appears after the soft parts have been to a great extent removed. The second specimen contains the entire Eustachian tube of the right side, from its pharyngeal orifice to its termination in the narrowed lower end of the middle ear. The third specimen consists of the membranous portion of the left Eustachian tube, divided transversely at a point about five inches from its pharyngeal orifice, and slit up longitudinally throughout a large part of its length. All the specimens are preserved in alcohol.

*The external auditory canal.*—The auricle had been cut away as close to the skull as possible, and all that remains of the cartilaginous portion of the canal is represented by two overlapping, funnel-shaped gutters of cartilage, which together form a complete conical framework around the skin-lined orifice of the external auditory canal. This orifice, which is nearly circular in shape, measures 9 millimeters in diameter. It enters the skull in a direction nearly parallel with the plane of the transverse vertical section. At a distance of about 2 centimeters from the orifice, the canal begins to bend backward in its course, and at the same time its calibre becomes considerably larger. At a distance of 7 centimeters from the external orifice it measures 15 millimeters in diameter. In the vicinity of the membrana tympani the calibre of the canal again diminishes in size,—to 9 or 10 millimeters, as nearly as I could ascertain. The ring of cartilage, representing, so to speak, the

insertion of the auricle, loses itself in the cutaneous lining of the canal at a distance of about  $5\frac{1}{2}$  centimeters from the outer orifice.<sup>1</sup> The entire length of the canal from the external orifice to the membrana tympani, measures  $16\frac{1}{2}$  centimeters, or about  $6\frac{1}{2}$  inches. The skin lining the canal,



Fig. 1. Vertical transverse section of the skull, a little in front of the external auditory canal. To expose the latter throughout the greater part of its course, the anterior wall of the bony cylinder has been chiseled away. (Reduced to one-third of the natural size of the parts.)

<sup>1</sup>In this particular specimen the canal was found to be filled throughout its entire length with a semi-solid material which looked like an admixture of cerumen and cast-off epidermis scales. The natural inference was, that the sedentary life and the unwholesome diet (candies, peanuts, etc.) to which show elephants are almost necessarily subjected, had produced this condition of what, in a human being, would be termed eczema.

for a distance of about 2 centimeters ( $\frac{3}{4}$  inch) from the orifice, presents a finely corrugated appearance, the folds running in a direction parallel with the long axis of the canal. From this point inward, as far as to the drum-membrane, it presents a smooth, almost polished appearance.

As may be seen in the figure, which represents the parts reduced to one-third of their natural size, the cylinder of bone constituting the external auditory canal lies in the midst of a labyrinth of intercommunicating cells or chambers of varying size and shape. About midway between the drum-membrane and the outer orifice this bony cylinder lies below a cavity of unusual size. How far this cavity extends upward I am unable to determine, as the upper part of the skull is not before me; but that part of the cavity which is visible in the specimen measures a little over 11 centimeters ( $4\frac{1}{2}$  inches) in its transverse, and at least 15 centimeters (6 inches) in its vertical diameter; this latter measurement extending from the surface of the section (superior transverse horizontal section) to the lower limits of that portion of the cavity which lies below and in front of the bony cylinder. All these (presumably) air chambers communicate freely with each other, sometimes by very broad openings. So far as I am able to find out by careful exploration with a probe and by forcing smoke through different channels, these cavities do not communicate with the tympanum proper, but do apparently communicate directly with the nasal system of cavities. In the human being the pneumatic cells do not communicate with the cavities belonging to the nasal system except through the Eustachian tube. In this respect, therefore, the mastoid cells<sup>1</sup> of the elephant differ materially from those of man.

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<sup>1</sup>In the human being pneumatic cells are found not only in the mastoid process, but also above the dense cylinder of bone which immediately surrounds the calibre of the external auditory canal,—that is, in the very same locality as that occupied by the cells here under consideration. Hyrtl, in

The *Eustachian tube*, from its pharyngeal<sup>1</sup> or nasal orifice to the point where it emerges into the tympanic system of cavities, measures 11 centimeters ( $4\frac{3}{8}$  inches). Its nasal orifice, in the present specimen, is more or less mutilated; but it is evident that in its general features and size it resembles very closely the pharyngeal end of the human Eustachian tube. The latter is perhaps a trifle larger, and it stands out more prominently from the surrounding surface of the mucous membrane. Toward the tympanum the tube ends in a nicely rounded orifice, one side of which apparently corresponds with the termination of the long and thick cartilaginous cylinder, around which the tube is curved, gutter-like. As the specimen had been preserved in alcohol for two or three months I was not able to make out satisfactorily, by simple naked-eye inspection, the exact relations of the different tissues of the tube to each other. At the two orifices the calibre appeared to be small, *i. e.*, simply large enough to admit easily a large-sized probe. A section near the middle portion of the tube revealed at first no calibre whatever, the opposite walls being apparently in perfect contact at all points. By manipulating the specimen, however, these closely applied walls could be made to separate, thus revealing to view a calibre large enough to admit the little and perhaps even the third finger. The top part of a question mark represents fairly well the cross section of the calibre of the tube, when in a state of rest, at a point about half-way between the two orifices. Toward the tympanum the tube does not open directly into

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his "Anatomische Untersuchungen über das Gehörorgan des Menschen und der Säugethiere" (Prag, 1845), says that "the pars mastoidea of the temporal bone is, according to Köstlin, wanting in the hippopotamus, the elephant, and the rhinoceros."

<sup>1</sup>The specimen is too fragmentary in character to warrant me in drawing any conclusion whatever in regard to the relations of the peripheral end of the Eustachian tube to the nasal and pharyngeal cavities. It is for this reason that I employ the terms pharyngeal and nasal indifferently.

the tympanic cavity proper, but into an elongated air chamber, which lies anteriorly to this cavity, and opens into it through an elongated slit-shaped opening. This chamber commences as a *cul-de-sac* at the orifice of the tube, and gradually increases in size, throughout a length of between 4 and 5 centimeters (about 2 inches). Like all the air chambers thus far mentioned, its walls consist of thin bone lined with a smooth mucous membrane. The antero-posterior diameter of the cavity, at a distance of  $3\frac{1}{2}$  centimeters from the orifice of the tube, measures nearly three centimeters ( $1\frac{1}{8}$  inches); the breadth varies but does not exceed  $1\frac{1}{2}$  centimeters ( $\frac{5}{8}$  inch) at any part. The opening from this chamber into the tympanum proper is an elongated slit and presents one or two peculiarities. The edge of the opening, on the side toward the median line, is provided with two odd-looking osteophytes, one resembling a cock's comb, the other a padded drum-stick, such as is used in beating a big bass drum. The slender handle of this miniature drum-stick is perhaps 4 millimeters long and scarcely half a millimeter thick, and at the end of it is a well rounded knob, fully two millimeters in length and about a millimeter and a half in thickness.<sup>1</sup>

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<sup>1</sup> Hyrtl says nothing about the occurrence of these osteophytes in the elephant in particular, but he refers to their existence in some animals in the following words: "In certain animals possessing a roomy tympanic cavity there are found, either in the middle ear proper or in some of the cavities which communicate with it, bony outgrowths of characteristic shape. As these objects are found, with rare exceptions, to be always of about the same size and to occupy relatively the same positions, the inference is permissible that they are not mere accidental formations, but probably possess some functional importance. \* \* \* \* \* \* \* In the posterior segment of the bulla [tympanica] of the lion these curious structures attain their highest degree of development, and may be seen here in the form of pear and other shaped bodies springing by a slender (sometimes hairlike) stem from the floor of this cavity." From this description, and also from the pictorial representations which he gives of these bodies, it is clear that they are identical with those which I have described above.

Still another peculiarity is observable at the opening which leads from the Eustachian vestibule, if I may so call it, into the tympanum proper. A little behind the opening the back wall of the vestibule becomes sharply grooved—very much like the groove of bone which, in the human being, holds the belly of the tensor tympani muscle—and runs upward, and finally a little forward to the anterior and middle portion of what may properly be termed the annulus



Fig. 2. View of the membrana tympani and grooved antero-external wall of the passage leading from the tympanum proper to the Eustachian tube. The sharp-edged ridge running along the middle of the grooved antero-external wall and dividing it into two subordinate shallow grooves, may be seen in the picture. (About one-third natural size.)

tympanicus. This groove extends so far outward that its outer wall is well outside of the plane of the drum-membrane. The anterior wall of the vestibule constituting one of the two grooves already mentioned displays three openings—two oval in shape and one nearly circular—which lead into adjacent air chambers; the other groove is smooth and free from openings throughout its entire length. The chambers just mentioned have no communication one with another, nor with any of the neighboring cavities. The antero-posterior diameter of the vestibule is 21 millimeters (nearly  $\frac{7}{8}$  inch). The breadth of the posterior wall, opposite the osteophytes, is 1 centimeter ( $\frac{3}{8}$  inch).

*The tympanic cavity.*—Looked at from below, this cavity seems to be separated into two parts by a projecting mass of bone, the sides of which form, roughly, an angle of  $45^{\circ}$ . That part of the cavity which lies nearer the median line is considerably larger than that which is in the immediate neighborhood of the drum-membrane. The roof of this outer cavity (or tympanum proper) pos-

seses certain peculiarities which will be described more fully by Dr. Richards.

The antero-posterior diameter of the tympanic cavity, directly abreast of the *membrana tympani*, is 27 millimeters ( $1\frac{1}{16}$  inches) and its average breadth 25 millimeters (about 1 inch). Its height could not be accurately ascertained, but it must have been at least 50 millimeters (2 inches).

The outer wall is made up of the grooved structures which I have described above, and of the *membrana tympani*. This latter membrane, which is shown fairly well in Figs. 2 and 4, is decidedly conical in shape, as seen from



Fig. 3. View of the tympanic cavity from within, showing (distinctly in the photograph but very faintly in the engraving) the stall-like openings behind and below the floor of the tympanum, a part of the jagged wall surrounding the mouth of the well-like excavation, the two osteophytes and the grooved outer wall of the passageway leading from the tympanum to the Eustachian tube. (Slightly reduced in size.)<sup>1</sup>

the side of the tympanum, while the surface of the membrane on the side toward the external auditory canal presents scarcely any hollowing-out at all,—barely enough to

<sup>1</sup>The difficulties encountered in photographing the middle ear from different points of view were found to be very great, and as a consequence the half-tone pictures which accompany this article leave very much to be desired in the way of clear definition.

justify the use of the expression, a shallow cone. This lack of agreement between the two surfaces is due apparently to two facts: the marked curving inward of the tip end of the manubrium mallei, and the great thickness of the soft parts in the vicinity of the umbo of the membrane. From the great resistance which the latter offers to pressure made at any point of its surface I should infer that its thickness is at no point less than one millimeter. As a whole the membrane is nearly circular in shape and measures fully two centimeters ( $\frac{3}{4}$  inch) in diameter.

Superiorly the tympanic cavity terminates in a *cul-de-sac* composed of soft tissues, which form a thick diaphragm separating the tympanum proper from a second, much smaller cavity containing the head of the hammer, all of the anvil, and presumably the stirrup. From the posterior part of this *cul-de-sac* the chorda tympani nerve passes forward, and then outward, in the form of a strong rounded cord, across the inner aspect of the neck of the hammer, at right angles to the manubrium. There is apparently no trace whatever of a tensor tympani muscle.

The comparatively small area of bone surface constituting the inner wall of the tympanic cavity proper presents, directly opposite the umbo of the drum-membrane, a rounded eminence in which no openings are visible. This is probably the analogue of the promontory in the human being. Behind it, and situated at a higher level, is a rounded ridge of bone which terminates in a hooded opening or niche, suggesting the niche for the *fenestra rotunda*; but a careful exploration with the probe fails to detect any break in the hard, bony surface at the bottom of the niche.<sup>1</sup> Further-

<sup>1</sup> Hyrtl (*op. cit.*) says that the *fenestra rotunda*, in the elephant, is to be found behind an angular overhanging projection of the promontory, and that the actual opening of communication between the tympanum and the *scala tympani* is a mere narrow slit. He quotes Cuvier as saying that the *fenestra rotunda* of the elephant is very small, irregular in shape, and concealed behind a projecting part of the promontory. At the same time

more, this niche faces forward and inward, whereas that of the *fenestra rotunda* in the human being faces backward and outward, and its position is altogether too far removed from the stirrup. The mere use of a probe is not sufficient to determine this question satisfactorily and I must, therefore, leave it unsettled. The rest of the inner wall of the tympanum, down to the point where it bends abruptly around the blunt anterior edge of the promontory described above, presents no features of special interest.

The posterior wall of the tympanum, in the vicinity of the promontory, is smooth, but on a line with the posterior margin of the *annulus tympanicus* it terminates abruptly in a thick, rounded edge which projects free into the air space. This edge represents the inner and lower termination of the bony cylinder constituting the external auditory canal. In the excavation behind and beneath the edge of bone just mentioned may be seen three sharp-edged membranous septa, dividing the space into three deeply-shaded recesses and one shallow *cul-de-sac*, all facing obliquely inward. Taking them in regular order from above downward I explored each stall with the probe, and found that the first one is a mere *cul-de-sac*, extending to only a slight depth. The second one, which presents the largest opening, measures 33 millimeters ( $1\frac{1}{4}$  inches) in length and runs apparently directly behind, and nearly in the same direction with, the external auditory canal. By withdrawing the probe a short distance and at the same time causing it to press against the antero-inferior wall of the channel, one becomes conscious that the end of the instrument reaches the free edge of an elastic septum that divides this second stall into two subordinate channels. The long axis of this second subordinate channel measures 30 millimeters ( $1\frac{1}{8}$  inches). The third stall is somewhat nar-

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he states that Fick (*Ueber das Labyrinth des Elefanten*, in Mueller's *Archiv*, 1844, p. 431) believes that this opening is the outlet of the aquæductus cochleæ, and that the elephant has no true *fenestra rotunda*.

rower at the entrance than the one just described. It consists apparently of a single passage without any bifurcations, and measures, from the entrance to its farther end, nearly 70 millimeters ( $2\frac{3}{4}$  inches). Its general direction corresponds quite accurately with that of the external auditory canal. The fourth stall has a length of 52 millimeters (2 inches), and its long axis, whose general direction is outward, forms an angle of about  $40^{\circ}$  with the axis of the external auditory canal. The floor is lacking close to the entrance, and the space is occupied by a deep excavation from which the probe passes downward into a large chamber.

The pit into which the stalls open is characterized by the presence, on its inner side, of a honey-comb structure which projects to such a degree as to partially conceal the entrances to the stalls. One of them is particularly conspicuous by reason of its perfectly cylindrical shape, by the jagged character of its free edge, and by the depth (20 millimeters— $\frac{3}{4}$  inch) of the enclosed well, which seems to have no communication with any of the adjacent cavities.

The large cavity which I mentioned in the earlier part of this description as forming an acute angle with the tympanum proper, presents few features of special interest. Its total length, or rather height, is approximately 50 millimeters (2 inches); its maximum transverse diameter is 30 millimeters ( $1\frac{1}{2}$  inches) and the minimum 20 millimeters ( $\frac{3}{4}$  inch). At the upper and back part of this subsidiary tympanic cavity are two triangular openings with smoothly rounded edges. The inferior opening seems to lead into the general system of air cells which surround the external auditory canal; the superior opening leads into a long cavity, or system of cavities, which certainly do not communicate with these cells. A probe introduced into this superior opening can be passed, in an outward and somewhat upward direction, to a distance of 85 millimeters

( $3\frac{3}{8}$  inches) without encountering any resistance. Several other openings are visible along the outer wall of the subsidiary tympanic cavity, but with one exception they all lead into shallow pockets or diverticula. In this single exceptional instance a slightly curved probe can be passed in to a depth of 25 millimeters (1 inch). This small curving cavity is situated in the mass of bone which forms the



Fig. 4. View of the subsidiary tympanic cavity as seen from within and behind, after the removal of the greater part of the anterior and upper boundaries. (Natural size.)

angle between the tympanum proper and the larger subsidiary cavity.

We come, finally, to the consideration of the small cavity lying above and behind the tympanum proper, the cavity containing the anvil, the body or head of the hammer, and presumably the stirrup. The plate of bone covering both this cavity and that of the tympanum proper was found to

be of considerable thickness, probably at least 5 millimeters ( $\frac{3}{16}$  inch) thick. This smaller cavity, as we have mentioned before, is entirely shut off from the tympanum proper. It is, roughly measured, about ten millimeters ( $\frac{1}{2}$  inch) square. From the forward and outer corner of this cavity a probe can be passed, in a direction parallel with the long axis of the external auditory canal, a distance of 55 millimeters ( $2\frac{1}{4}$  inches) before it encounters any obstacle. By the smoke test it appears that this cavity or channel is a closed sac, having no communication with the adjacent system of pneumatic cells, and therefore not representing, in a physiological sense, the analogue of the mastoid antrum in the human being.

The space between the tegmen tympani and the head of the hammer and body of the anvil, was found to be filled with a mass of soft connective tissue (almost like adipose tissue). Its removal disclosed to view the interlocking malleo-incudal joint. The body of the anvil overowers the head of the hammer; that is, it is decidedly nearer the tegmen tympani. There is quite free play between the two ossicles, both of which, however, may be described as being very solidly anchored in their respective positions. Considerable force may be applied to the handle of the hammer near the umbo of the membrana tympani before any visible excursion of the head of this ossicle can be distinguished. The same degree of force applied to the handle of the hammer apparently fails to produce any motion whatever in the anvil. Direct pressure upon the latter must be of a very decided character before visible motion can be excited in it. A strong membranous capsule spans the space between the opposite edges of the malleo-incudal joint.





